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Field measurements of extreme waves in the intertidal zone, Aran Islands, Ireland

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Project

This collaborative international project (2015-present) addresses knowledge deficits in the study of storm waves and their interaction with steep rocky coasts. Combining field measurements of boulder creation and boulder movement, instrumentation in the shallow offshore area and on supratidal platforms, numerical and analytical modeling [3], and physical wave-tank experiments, we are working to generate a synthetic understanding of relationships between coastal wave energy, onshore flow, and mass transport.

Field Work

Field campaigns were undertaken on the Aran Islands off the west coast of Ireland. Before-and-after photography was used to produce a database of >1100 boulders moved by storm waves during winter 2013-2014 [2]. The largest boulder moved was 620t. Boulders were relocated at elevations up to 26m, and at distances up to 220m inland. New boulders, weighting 10s of tonnes, were extracted from bedrock. An ADCP deployment over 3 month in 40m water depth 3km off the Inishmaan coast yielded wave data in intermediate to shallow water depth. Extreme loading and aeration of the water makes acoustic doppler devices infeasible in shallow water. Three custom made pressure sensors were deployed at three sites on Inishmaan. Profiles vary from a near vertical cliff to a flat bedrock platform. Two successful campaigns during the winters of 2016/17 and 2018/19 with 100% data return have already been completed, a third deployment will be retrieved when weather permits.

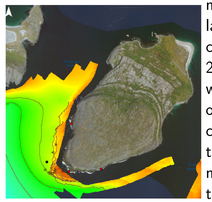

Figure 1: Location of pressure sensors (red) and ADCP (black)

Reconstructing Surface elevation from bottom mounted pressure sensors – The issue

- Literature focusses on intermediate and deep water situations
- Only very recently extension of methods to higher order up to the breaking limit for *progressing waves* [1]
- Pressure traces affected by water motion varying from linear progressing to fully reflected waves, plunging breakers, swash or bores with varying tidal elevation

Experimental Tank Testing

Experimental tank tests were performed in the wide wave basin in the Marine Laboratory, QUB at 100th scale. The tank bottom slopes from the deep section, where the Edinburgh Design Ltd. absorbing wavemaker is installed, to an absorbing beach. Experiments were performed for two water levels (4 and 2cm) and seastates ($H_s = 0.06m$, $T_p = 1.2s$ and $H_s = 0.12m$, $T_p = 1.2s$). A vertical wall was installed $6cm$ from the shallowest probe position to investigate the effect of a vertical cliff face. IP68 vented gauge pressure transducers (25Y models by Keller Ltd.) were installed flush with the tank floor. Resistance wave gauges were placed directly above the sensors. All sensors recorded with 128Hz.

Figure 2: Experimental setup in the wide wave basin, QUB. 100th scale. The wavemaker (right) creates waves which transform while progressing over the rising bathymetry towards the beach/cliff (left).

Are we missing significant coastal wave events?

Figure 3: View over a submerged platform below a cliff on the field site on the Aran Islands. Boulder deposits are visible on the cliff top. High aeration levels of the water make the use of Acoustic Doppler equipment unfeasible.

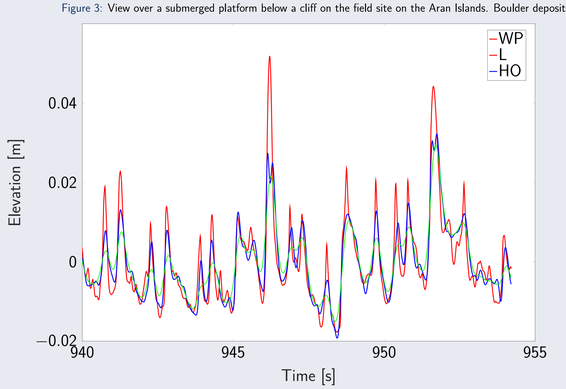

Figure 4: Example experimental time trace. 100th scale. Water depth $2cm$, $H_s = 12cm$, $T_p = 1.2s$. Data is shown for the resistance wave probe (WP), hydrostatic reconstruction (L) and higher order correction (HO).

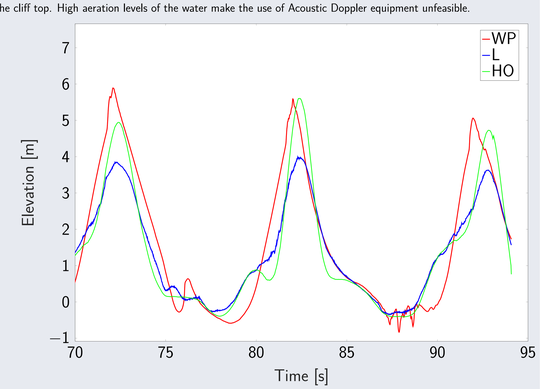

Figure 5: Example time trace of simulation results. Full scale. Probes are located at the platform edge as shown in Fig. 6 a. Wave period is 6s, still water level $14m$, the platform rises 10m

Numerical Tank Testing

A custom numerical wave tank [4] based on interFoam of the OpenFOAM-v1806 toolbox allows for easy variation of bathymetry, water level and access to field variables. Tests are run for different platform shapes (square and sloped Fig. 6). A wall conditions simulates a cliff face at the platform end. Three numerical wave probes record surface elevation across the length of the platform or slope. Corresponding pressure probes at the bottom record data similar to our setup in the field.

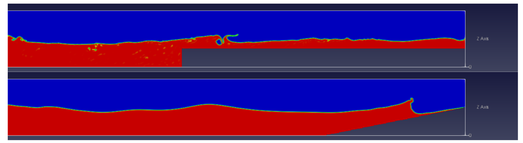

Figure 6: Example bathymetries under investigation in the numerical wave tank. Waves propagate from a low reflection wavemaker on the left towards a cliff face on the right. Simulations are run using OpenFOAM-v1806 and a custom numerical wave tank. [4]

Results

- Results indicate 30% higher mean wave height and up to 100% higher extreme wave events than predicted by hydrostatic reconstruction from pressure sensors
- Non-linear reconstruction [1] somewhat better but often not applicable
- ADCP measurements in those location unfeasible due to aeration and loads
- Urgent need for review and better post-processing of pressure data measurements in the near shore region
- Alternative measurement techniques are required

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Acknowledgements

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Photography encouraged